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Taxonomy of competence models based on an integrative literature review

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Abstract

An individual competence is one of the main human resources, which enables a person to operate in everyday life. A competence profile, formally captured and described as a structured model, may enable various operations, e.g., a more precise evaluation and closure of a training gap. Such application scenarios supported by information systems are particularly compelling for the era of digitalisation, although research on adequate models capturing competence profiles is still lacking; moreover, no research was revealed synthesizing models of competence, enabling operationalisation possibilities. To fulfil this gap, current research develops a classification of competence models in the form of taxonomy, derived from operational characteristics of competence constructs. Given conceptual fuzziness of the competence term and complex, interdisciplinary scope of the study, the research method follows integrative literature review principles: results of an extensive search conducted in three iterations were critically analysed and further synthesized in the form of taxonomy. This critical analysis was performed based on an overview of twenty-four competence models with a lens of working definitions of competence framework and model concepts. As a result, all three outcomes highlight the power of competence models: (1) the overview summarises models' development methods, operationalisation, and purposes in a specific application domain, while (2) working definitions and (3) the taxonomy aim at overcoming a conceptual ambiguity of competence concepts. In addition, the presented taxonomy may serve as a knowledge base or a decision support tool on competence model selection when it comes to development of a competence management tool.

Keywords Competence · Competence Model · Taxonomy · Integrative Literature Review

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1 Introduction

1.1 Research motivation

The term of *competence* is distressed by both phenomena of polysemy and synonymy, when one can approach the same term with different meanings and other way around (Antera, 2021). The competence research movement takes its origin from the psychological domain through works of White (1959) and McClelland (1973), their research has contributed significantly to the development of the education research: both scholars emphasized a holistic meaning of competence and its contribution to the overall development of a personality and human intelligence within educational and development domains. Though most researchers would treat McClelland as a founder of the "modern competence movement" in early 1970's, the understanding of the concept of competence remained ambiguous and fuzzy since then (Le Deist & Winterton, 2005; Stevens, 2013).

In addition to the synonymy and polysemy issues, the terms of "competence" and "competency" are interchangeably used in literature as well, although these terms underline different personal characteristics (Le Deist & Winterton, 2005; Moolman, 2017; Teodorescu, 2006; Vare et al., 2022). Scholars noted that "it has become the convention to use the plural "competences" when referring to occupational standards" in the UK, although "when referring to competence in a more general sense, the plural "competencies" is applied (Cheetham & Chivers, 1996). Later, to synthesize various international perspectives and interpretations of the competence concepts, Vare et al. (2022) presented a competence concept map on how the term may be understood.

Despite the fact, that no consensus is achieved in defining the competence, as well as competency models and frameworks, these phenomena are extensively researched and often linked to a specific occupation and standard, which would define a relevant level of performance (Glaesser, 2019). A *competency model* is defined by Marrelli et al. (2005) as "an organizing framework that lists the *competencies* required for effective performance in a specific job, job family […], organisation, function, or process". Respectively, Stevens (2013) defines *competency modeling* as "an attribute-based form of work analysis", which heavily focuses on "future roles that align with a strategic plan and defining maximum performance in those roles through worker attributes". A *competency framework* is defined by George (2022) as "a structure that sets out and defines each individual *competency* […] required by individuals working in an organisation or part of that organisation", in addition, Le Deist and Winterton (2005) highlights that a *competence framework* is usually considered as "a mechanism to link human resource development with organisational strategy". From these four different definitions, one can see that the concepts of competency model and competency framework are also interchangeably and synonymously used by scholars (this aspect of conceptual confusion will be addressed and clarified later in the paper). Despite the conceptual ambiguity, competency models may become particularly useful to systematically approach human resource development (Stevens, 2013)

and management (Marrelli et al., 2005), and would be beneficial for enhancement of education and graduates' employability (Moolman, 2017).

The fuzziness of the competence definition in educational research was already highlighted by Hartig and Klieme (2006) and Koeppen et al. (2008). Overcoming this ambiguity is crucial for adequate competence modeling and assessment: relevant measurement approaches should be adapted and advanced, "given the complexity of competence constructs" (Koeppen et al., 2008). In this context, reliable measurement of competences is particularly important nowadays since technology-based assessment of competences is "driven by the rapid development of computer technology rather than by well-founded theories", while to secure valid competence measures, one should base them on "theoretically sound and empirically tested competence models" (Koeppen et al., 2008). Therefore, for advancing research and competence concepts, scholars provide the next two definitions of theoretical models (Hartig & Klieme, 2006; Klieme et al., 2008):

- "*Models of competence levels* define the specific situational demands that can be mastered by individuals with certain levels or profiles of competencies", which are "particularly useful for assessing and evaluating educational outcomes". This describes to which degree or on which level a competence is present or needed.
- "*Models of competence structures* deal with the relations between performances in different contexts and seek to identify common underlying dimensions", which are "especially interesting for explaining performance in specific domains in terms of underlying basic abilities and can provide a basis for more differentiated measurement results of individual-centred assessments". This describes which elements or sub-constructs a competence description includes and how they are related.

According to our understanding, the definition of a competence model can involve both, the models of levels and the models of structures. For modelling the complexity of competences both might be needed. Therefore, in the following analysis competence models with models of levels, models of structures and combinations of both are considered.

Measurement of competences is only one example of possible application domains in education. Giving competences an operational aspect,—understanding "what do they basically mean",—will allow them becoming a resource rather than a conceptually ambiguous problem (Vare et al., 2022). "Operational aspect" includes, among others, aspects of defining "rules used to assign a value to what is observed, and how to interpret the value" (Engel & Schutt, 2014), and *operationalisation* can be defined as "the translation of concepts into tangible indicators of their existence" (Saunders et al., 2012) or as "the process of specifying the operations that will indicate the value of cases on a variable" (Engel & Schutt, 2014). Operationalisation according to our understanding is the way how the competence models are used, e.g., for competence assessment, and how they are interpreted. In case of competence operationalisation, breaking down its concept into sub-constructs may help to indicate possible operations and application scenarios.

The aim of this literature research study is to advance theoretical research on the competence concept by creating a taxonomy of competence models, which is mainly focusing on competence operationalisation (meaning: what are the competence models good for, and how they are used). The paper comprises four chapters: stating the research motivation and related research questions will accomplish this chapter; a disclosure of the research method enabling a selection of 24 relevant papers out of 3029 detected items, which are then summarised in the overview of competence models, will happen in the second chapter; the taxonomy development and discussion will be an essence of the third chapter; a summary of the conducted research, future implications and limitations will conclude this paper in the form of the last, fourth chapter.

1.2 Related studies

To bring competence research forward, and not to develop new (meta-) frameworks, scholars tend to build taxonomies of competences based on already existing frameworks and standards. This way, a *Taxonomy of Essential Competencies for Program Evaluators* was established by Stevahn et al. (2005) as a crosswalk of three relevant professional standards and four types of competent evaluators were defined by proficiency levels. The same year, a French research group published a typology of competence adopted from Cheetham and Chivers (1996) together with a holistic model of competence of Le Deist and Winterton (2005) based on analysis of different occupational standards and competence frameworks. Later on, this model served as a foundation of the *Typology of knowledge, skills and competences* (Winterton et al., 2006) and as a reference model for analysing earlier-developed (1964–1996) models of competence (Winterton, 2009).

Among more recent findings, Seemiller and Whitney (2019) developed a learning taxonomy to reflect leadership competency development, as well as Nijhuis et al. (2015) developed a taxonomy for project management competences. In 2021, a taxonomy of social-emotional competences called "*DOMASEC*" was developed to link relevant terms and constructs across established frameworks and disciplines (Schoon, 2021). Such an integrative alignment helps to guide the conceptualisation and operationalisation of competences (Schoon, 2021) and eventually brings it to the holistic definition and understanding of the competence concept (Antera, 2021).

Nevertheless, the above-mentioned taxonomies represent competences within domain-specific competence frameworks, and do not grasp competences holistically. For instance, Luiz Neto et al. (2022) develop a "consolidated matrix" and a "cognitive map" to describe the evolution of learning and to classify competence levels, respectively; these developed concepts claim to contribute to professional competence assessment. But given the context-specificity, learning and competence acquisition should happen in domain-specific situations (Koeppen et al., 2008), and since the authors do not connect the developed concepts to specific competence models/structures, those lack a situational context and, therefore, limit their further application.

From this short discourse, one may notice that there have been certain deficiencies in a sound, elaborated research on competence models, which would contribute to studying "the interaction between individual abilities and the environment, different levels of competence, and developmental processes" (Koeppen et al., 2008); more than a decade ago, the researchers were highlighting that adequate models to capture "contextualized competence constructs" were "still lacking". As previously mentioned and as will be summarised again in the next subchapter, the issue of a competence fuzziness still remains unsolved today (Antera, 2021; Vare et al., 2022). In addition, as will be shown in the second chapter, no taxonomy or similar classification was revealed to describe and classify *models of competence structures*, dealing with interrelations between competence sub-constructs; this makes the study even more attractive for scholars and practitioners interested in application of competence concepts and models. Such applications supported by digitally-processed competence data were proved to be useful for both students and teachers, particularly when it comes to planning competence development journeys (Mikhridinova et al., 2022) or empirical assessment of competences (Klieme et al., 2008) in complex, real-life scenarios (Baaken et al., 2015; de Los Ríos et al., 2010). In a global sense, an adequate and contemporary competence research supported by "theoretical models of competence" advances development of entire educational systems (Klieme et al., 2008).

1.3 Problem statement and research questions

Competence is a complex and ambiguous concept which makes the competence research spread across multiple disciplines. In formulating research agendas on the competence topic, researchers emphasize a need for "clear conceptual distinctions" (Glaesser, 2019), understanding what constitutes the competence construct and how to operationalise (Deardorff, 2015) or measure it (Murawski & Bick, 2017). However, valid measures of competences should be based on "theoretically sound and empirically tested competence models" (Koeppen et al., 2008), and before measurement or other operations, there is a need for concept definition, particularly when the concept is "surrounded by high confusion" (Antera, 2021).

As shown previously, no research was revealed so far trying to synthesize and integrate models or structures of competence with an overview of relevant application domains, sub-constructs, and operationalisation possibilities. To fulfil this gap, this research aims at answering the following research questions (RQ):

RQ1: What is a competence model formally capturing competences or competence profiles, and which types of these models do exist in a recent literature?
RQ2: Are there taxonomies or typologies of competence models in the sense of RQ1 already available and validated? If not, how such a taxonomy may look like?
RQ3: What characteristics and features do these competence models have in respect to application and operationalisation scenarios?

As highlighted above, the competence term is a vague and ambiguous concept, and a subject of polysemy and synonymy issues, meaning that different terms may be used to represent the "*competence model*" as well as other way around: the term of "*competence model*" can represent a competency model/framework, which is out of scope of the current research. To emphasize the scope of the study, there is a need to highlight that two definitions of "*model of competence levels*" and "*models of competence structures*" given by Hartig and Klieme (2006) and Klieme et al. (2008) will be particularly considered while searching for the literature sources. The "*model of competence levels*" can be associated with competency model/framework and relevant standards. While the "*model of competence structures*" is very interesting for the current research, as this definition assumes a formal description of a competence. This will be the current understanding of the structure behind a "*competence model*" in this research. Nevertheless, Koeppen et al. (2008) also highlighted that both models complement each other, what can mean, that a competency model/framework may be based on a formal description of a competence structure; this view will be particularly considered for building the search and selection strategy of the research method.

2 Research method

2.1 Methodology

Considering the conceptual fuzziness of the competence term, and a potential spread across multiple disciplines, the research followed at the beginning an exploration strategy to capture a wider range of research papers (Stevens, 2013) on the formal description of competences and competence models. Later, the selected sources were critically analysed to narrow down the research towards its initial scope, formed out of the research questions (RQ's) and supported by definitions (Def's) given in the previous chapter (Fig. 1). To get the required answers to the questions stated above, and given the complex scope of the study, the method of integrative literature review was selected to follow (Robin & Kathleen, 2005; Snyder, 2019; Torraco, 2005). This type of literature review creates transparency through an extensive search strategy, and based on a critical analysis synthesizes available sources to create new frameworks and perspectives. A taxonomy constitutes one of such frameworks, namely a "conceptual classification of constructs" (Torraco, 2005). The advantageous role

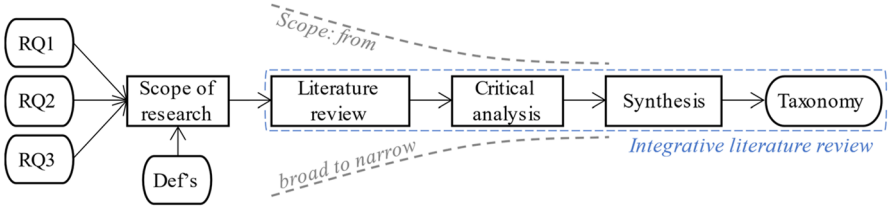

Fig. 1 Research process flowchart

of applying taxonomies is recognized in information systems literature and in other domains like pedagogy, as it contributes to structural organisation of knowledge, and theory building in general (Nickerson et al., 2013). In frames of this study, the taxonomy aims to overcome the conceptual ambiguity of the competence term by:

- synthesizing competence sub-constructs in a structured classification,
- looking at how competence model can be formally described, and
- what operational aspects it can grasp.

As was already highlighted by Vare et al. (2022), understanding what the competences "basically mean" will allow them becoming a *resource* rather than a *conceptually ambiguous problem*; in terms of the selected methodology,—one should rather focus on understanding the concept than just consolidating various definitions of it.

The taxonomy term is often confused as classification, typology and taxonomy are claimed to be used interchangeably (Bailey, 1994; Doty, 1994; Nickerson et al., 2013). Although typology is different from taxonomy as the first one determines a conceptual classification, and the latter – an empirical one (Bailey, 1994), the term of taxonomy is the most used one among objects' grouping systems disregard the type of classification (Nickerson et al., 2013). A central problem in taxonomy development is a selection of the relevant dimensions and characteristics, which can be done inductively, deductively or intuitively; besides, it is advised to employ an iterative approach to arrive at the useful taxonomy (Nickerson et al., 2013). Therefore, in case of finding a similar taxonomy or other classification of competence models in surveyed papers, it is assumed that it can be used as a basis for further iterative development of the current taxonomy.

2.2 Literature review strategy

Since the competence research lies across different disciplines, the subject areas were not limited to one specific domain but instead considered various areas (see Table 1), where the formal description of an individual competence profile would be of interest.

To make sure that only papers in their final published shape are included in the search, the range of publication years was limited by the year of 2022 and included recent journal articles published since 2017. As a source type, journal papers were selected since the competence concept has been highly researched and journal publications may guarantee a higher quality due to a peer-reviewed mode. The two databases of (Elsevier) Scopus and Web of Science were selected as the first one provides a good overview of global research and latter one – represents a multidisciplinary database of high-impact journals (Dresch et al., 2015). The content of titles, keywords and abstracts was determined by terms used by Le Deist and Winterton (2005), McClelland (1973), Stevens (2013), and Vare et al. (2022) as well as by mind mapping of possible terms representing "model", "formal description" and "taxonomy" (Nickerson et al., 2013). Firstly, the search was based on relevant

Table 1 Criteria of the search strategy

Criterion	Value
Database	Scopus, Web of Science
Period	2017 – 2022
Textual content	Title, keywords, and abstract
Source/document type	Journal/article, review
Subject/research areas	Automation Control Systems, Business Economics, Business Management and Accounting, Computer Science, Decision Sciences, Economics, Econometrics and Finance, Education and Educational Research, Engineering, Health Professions, Information Science and Library Science, Mathematical Methods in Social Sciences, Mathematics, Medicine, Multidisciplinary, Operations Research & Management Science, Psychology, Science Technology, Social Sciences
Language	English
Publication stage	Final
Search string, iteration 1	TITLE("competenc* model*") AND KEY("competenc* model*" OR "competenc*") AND KEY("approach*" OR "set" OR "analysis" OR "structur*" OR "metamodel" OR "system*" OR "archetype" OR "aptitude" OR "taxonom*" OR "repre*entation" OR "formal*" OR "formulation" OR "concept*" OR "breakdown" OR "description" OR "catalog*" OR "dictionar*" OR "operationali*ation" OR "structur*" OR "typolog*") OR ABS ("approach*" OR "set" OR "analysis" OR "structur*" OR "metamodel" OR "system*" OR "archetype" OR "aptitude" OR "taxonom*" OR "repre*entation" OR "formal*" OR "formulation" OR "concept*" OR "breakdown" OR "description" OR "catalog*" OR "dictionar*" OR "operationali*ation" OR "structur*" OR "typolog*")
Search string, iteration 2	KEY(competenc?) OR KEY(aptitude) OR KEY(skill) OR KEY(competenc?-based) OR KEY(skill?-based) OR KEY(aptitude?-based) AND KEY(model) OR KEY(framework) OR KEY(set) OR KEY(archetype) OR KEY(formulation) OR KEY(representation) OR KEY(catalog) OR KEY(conceptuali?ation) OR KEY(structure) OR KEY(systemati?ation) OR KEY(taxonomy) OR KEY(typology) OR KEY(definition) OR KEY(description) OR KEY(formali?ation) OR KEY(metamodel) OR KEY(catalog?) OR KEY(catalog??) OR KEY(taxonom??) OR KEY(typolog??)
Search string, iteration 3	KEY ("competence" OR "competency" OR "competence-based" OR "competency-based" OR "skill-based") AND KEY ("model" OR "models" "approach" OR "framework" OR "analysis" OR "taxonomy" OR "representation" OR "formalisation" OR "formulation" OR "concept" OR "breakdown" OR "formal description" OR "catalogue" OR "dictionary" OR "operationalisation" OR "structure" OR "typology") AND ABS ("model" OR "models" "approach" OR "framework" OR "analysis" OR "taxonomy" OR "representation" OR "formalisation" OR "formulation" OR "concept" OR "breakdown" OR "formal description" OR "catalogue" OR "dictionary" OR "operationalisation" OR "structure" OR "typology")

titles and keywords combination and used an exact search as well as "*"-wildcard to represent several unknown characters; this is mostly done due to the different usage of the competence term (Stevens, 2013) as well as due to the different writing in British and American English. To report the flow of literature search and relevant

sources identification, the PRISMA statement (Liberati et al., 2009) was chosen and adapted (see Fig. 2).

As can be seen in Fig. 3, the first search yielded only in 102 items of research papers. Among these 102 items, terms like "competence-based approach" were

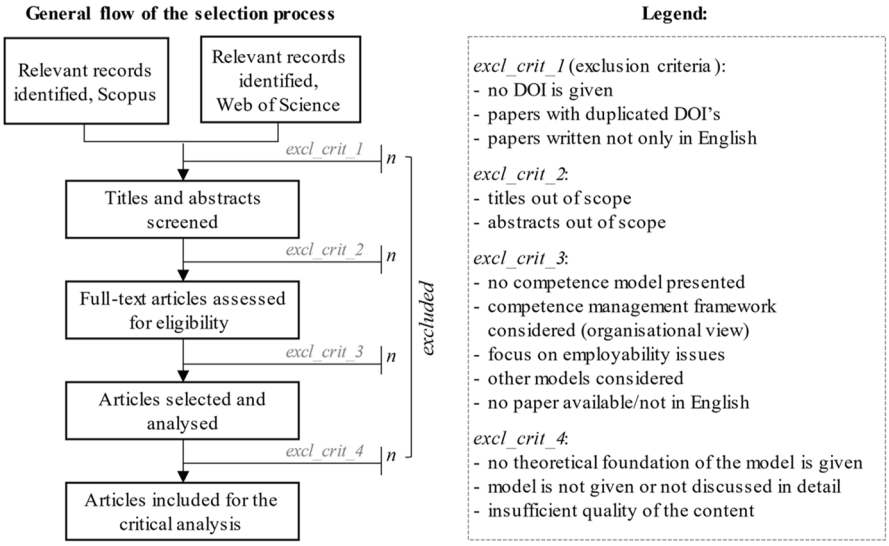

Fig. 2 Papers' selection process based on the PRISMA statement (Liberati et al., 2009)

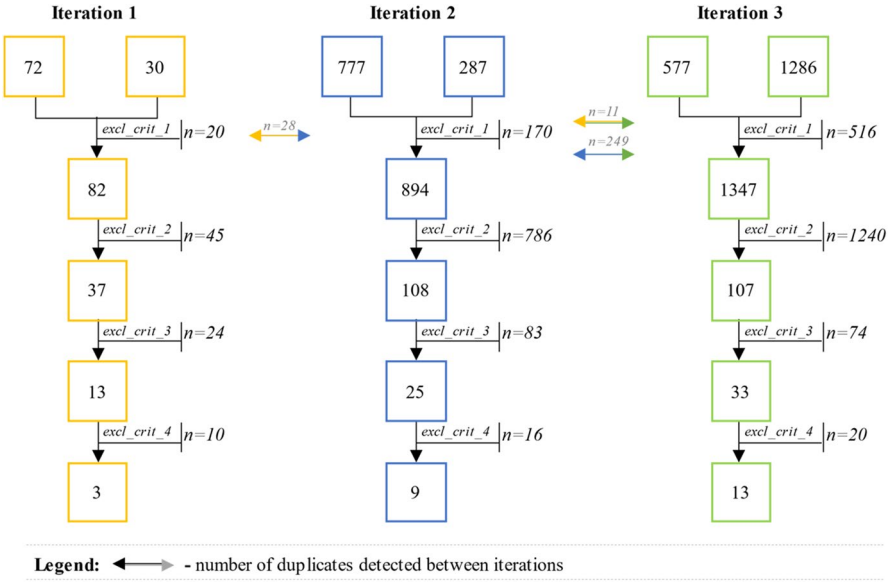

Fig. 3 Papers' selection process in three iterations

often used in addition to "competence model", and therefore, it was decided to iterate the search with different search strings based on this finding. This way, the second iteration focused only on the search of keywords combination; here "?"-wildcard was used to represent a single character due to the general use of relevant syntactic combinations. The third iteration searched for papers based on combination of keywords and abstracts without the wildcard application (Table 1).

As a result, search strings of the second and third iterations generated ten and eighteen times more items, respectively, than the first iteration. To guarantee a systematic selection process, exclusion criteria (*excl_crit*) were set as shown in Fig. 2. Criteria *excl_crit_1*- and *excl_crit_2* were applied in set-up spread sheets by means of Microsoft Excel, where bibliographic data of publications were analysed.

Important to mention that before applying *excl_crit_1* to items of the second and third iterations, a detection of duplicates between the iterations was done, which led to the exclusion of 288 duplicated items (Fig. 3).

To fasten the screening process of titles and abstracts, the next filtering approach was created based on the scope of the current literature review:

- titles and keywords of papers were screened for terms of "aptitude", "competenc*" and "skill", and then
- abstracts were screened for the same terms, and in addition for terms like "framework", "set", "archetype", "formulati*", "represent", "catalog", "conceptuali*", "structure*", "systemi*", "taxonom*", "typolog*", "defin*", "descript*", "formali*", and "metamodel".

This approach was reflected as (1;0) set in rows of respective items, which were summed up per titles, keywords, and abstracts. First, titles were checked: those items with the sum of binary results equal "0" (in titles and keywords) were excluded, then, the remaining items were checked (read and analysed towards the scope of the current research) in combination with keywords. Then, the abstracts of released papers after the titles' check were screened the same way: those with "0" results in abstracts were sorted out, and remaining ones were checked in combination with keywords. This filtering approach allowed a faster screening process based on the assumption: the more terms of interest are included in titles, keywords, and abstracts, the higher is a chance to find a paper on the scope of the study. Therefore, papers with a bigger sum in relevant rows of titles, keywords, and abstracts were more carefully checked, than those with smaller sum values. Screening of titles and abstracts yielded in 252 remaining items of research papers.

Spread sheets in Microsoft Excel may support a "first level of coding" but shouldn't be used for further analysis since those are rather a repository tool (Bandara et al., 2015). Therefore, on the next stage, every full paper was individually surveyed to assess eligibility based on the checklist principle (Barbour, 2001; Okoli & Schabram, 2012), described by a flowchart shown in Fig. 4. This process flow was realised by means of Microsoft Forms to get a systematic overview of the surveyed items. Under scope-out reasons *excl_crit_3*-criteria were listed, under "main construct" – competency, competence, skill, or "other" constructs were foreseen, and

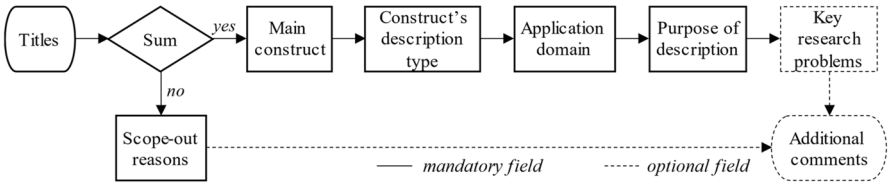

Fig. 4 Process flow of the full papers' survey

under "construct's description type" – the type of competence model description. The survey released 71 papers for further analysis.

The main purpose of this stage of literature review was to capture every formal description of competence models without critical analysis of the content, which is foreseen on the next step.

2.3 Critical analysis and synthesis

Critical analysis invites authors to break down a literature research topic into its fundamental elements like main concepts and relationships among them, applications of the topic and other characteristics. A critique lays a basis of critical analysis, which helps to identify strengths and deficiencies of considered literature (Torraco, 2005).

In case of the current research, the main concept is a competence model, and on a previous stage it was decomposed to considered sub-constructs and their description type. The main critique towards the resulting overview may be formulated as follows: (a) whether the quality of considered papers is sufficient, which resulted in *excl_crit_4* (no given theoretical foundation of the model, competence model is not discussed in detail, and insufficient quality of the content); (b) whether it gives a clear picture of the next characteristics of competence model description:

- type of description,
- type of competence model,
- main construct and its elements, and
- purpose of the description/model development.

Application of this critique resulted in 24 papers. Most of the papers were sorted out due to insufficient quality of research presented and/or focus laid mostly on skills rather than competence concepts. Semantic analysis in the form of word frequency query for (a) automatically identified themes, and (b) author keywords and abstracts can be found in Fig. 5. The query was run on NVivo qualitative data analysis software with minimum length of four symbols and displaying fifty-most frequent words. As may be noticed, the themes, as a common content of papers, as well as keywords and abstracts reflecting the scope of papers enjoy different wordings of the competence term. As highlighted by Tang (2023), it is not recommended to imply auto-coding for themes when the analysis requires "close, interpretive reading

Fig. 5 Word frequency of (**a**) automatically identified themes, (**b**) keywords and abstracts

of the data". Therefore, these two figures are placed only to create a first glance on the content of papers and to confirm again a need to critically analyse the selected papers rather than rely on automatically detected themes.

The next step is synthesis of 24 selected papers such as integrating existing and new ideas to create a taxonomy. The overview of the chosen models, alphabetically ordered by respective authors, is given in Table 2.

The table summarizes labels (names of the constructs) as given by authors, competence constructs' operationalisation, purposes, and development methods of the models, as well as respective research areas addressed, without a further synthesis yet. Nevertheless, the table shows how the selected models were developed and how the competence elements were operationalised to fulfil the models' purposes in a specific application domain and research areas. Most of the papers were published in 2017 and frequently address *Computer Science* research area, coded as R2; codes of research areas (explained at the bottom of Table 2) enable an easier grasping of research fields addressed, particularly when it comes to their combinations.

As can be noticed, a formal description of competences is widely applied within and across various disciplines, and often addresses training and education purposes. The competence constructs (*Operationalisation* column) underline competence elements which should be determined to enable *Purpose of the Model*. For that, *skills* and *knowledge* are often mentioned to be applied, combined with either *abilities* (Bohlouli et al., 2017; Uhm et al., 2017) or *attitudes* (D'Aniello et al., 2021; Gaeta et al., 2017; Salman et al., 2020; Zandbergs et al., 2019). Although authors use the *KSA* abbreviation (K – knowledge, S – skill, A – ability/attitude) to reflect these three elements, it is not employed in the table to avoid possible confusion. On the opposite, authors are consistent in using the *KSAOs* term, namely *knowledge, skills, abilities, and other characteristics* (Fernández-Sanz et al., 2017; Schulze et al., 2017), therefore, the term is employed the way it is. Another insight is that the *Model's Label* column represents a "zoo" of various concepts: scholars interchangeably use *framework* and *model* terms, or both – as in case of *Framework of the Star-Chef Competency Model* (Suhairom et al., 2019).

The derived overview is a useful outcome of this study by its own: it summarises formally captured "competence" models developed in 2017–2022 period and applied in various research areas. Although those models are not always called competence

Table 2 Overview of the selected competence models

ID	Authors	Model's Label	Purpose of the Model	Development Method	Operationalisation	R.A.*
1	(Bohlouli et al., 2017)	Competence tree	Optimal job assignment, vocational training, other recruitment processes	Adoption from Bohlouli et al. (2015)	Hierarchy-based competence tree with weighted nodes; weighted competence scores of acquired and required competence data	*R2; R5; R12*
2	(Child & Shaw, 2020)	Broader competence concept	Domain competence conceptualisation, developing progression indicators	Deconstruction of the competence into working concepts	Broad competency deconstructed in sub-domain competencies, themes, characteristics, and progression indicators	*R4*
3	(Costa & Santos, 2017)	Conceptual model for the data scientist profile	Data scientist profile conceptualisation	Evaluation of the representativeness of the profile in e-CF and SFIA frameworks	Knowledge base and skills set; competences associated with proficiency levels (e-CF), skills—with responsibility levels (SFIA)	*R8*
4	(D'Aniello et al., 2021)	Lightweight semantic competence model	Competence-based team selection process	Adoption from Gaeta et al. (2012)	Knowledge, skills, and attitudes (with relevant level of mastery and expertise), arranged in a hierarchy	*R2; R5; R12*
5	(El Asame & Wakrim, 2018)	Model as a rich data structure	Training and education, personalisation of learning activities	Overcoming limitations of HR-XML and IMS RDCEO specifications	Proficiency level (skills and knowledge), competency level (demonstrating the performance), context	*R4*
6	(Feng & Richards, 2018)	Competency scheme	Digital curator profile conceptualisation	Coding based on a typology for competency (Le Deist & Winterton, 2005)	Four types of professional competency (cognitive, functional, social, and meta-competency) with relevant subcodes	*R8*

Table 2 (continued)

ID	Authors	Model's Label	Purpose of the Model	Development Method	Operationalisation	R.A.*
7	(Fernández-Sanz et al., 2017)	eSkills Match framework	ICT profile conceptualisation	Integrating profile descriptions from different frameworks via entity relationship diagrams	KSAOs; proficiency level (reference level in EQF) for a competence, applied to sublevels of skills and knowledge	*R2*
8	(Gaeta et al., 2017)	Competence ontology	Analysis of real gaps in employee's profiles, suggestion of learning activities	Extracting competences from job descriptions and employees' curricula vitae	Competency (skill, knowledge, attitude), context, assessment (scale, level, evidence), and weight to measure the competence gap	*R2; R16*
9	(Gasmi & Bouras, 2017)	Competency class of the ontology model	Profile matching between individual curriculum and occupation competencies	Semantic modeling based on O*NET, ROME competency formalisation methods	Sub-classes (ability, skill, knowledge), importance (required, preferred, desired) and required competency (knowing, capable, competent) levels	*R2; R5; R16*
10	(Heller et al., 2017)	Competence model, structure	Unique skill assessment based on cognitive diagnostic model	Skill-based extension of the theory of knowledge structures	Skill function based on pairwise incomparable competencies, and competence states as subsets of skills	*R9; R10; R13*
11	(Korytkowski, 2017)	Hierarchical competence graph	Relation between performance and required/possessed competences	Mathematical modeling, and applying Performance Evaluation Algorithm (PEA)	Elementary competence with relevant experience level; learning, forgetting rates; relations between competences; competence relation force	*R2; R5; R12*

Table 2 (continued)

ID	Authors	Model's Label	Purpose of the Model	Development Method	Operationalisation	R.A.*
12	(Li et al., 2020)	Multidimensional scaling map	Insights on project manager competences in developing countries	Content analysis and multidimensional scaling using Proxscal algorithm	Attribute- and performance-based competence categories; competence variables grouped in competence sets, and laid on two dimensions	*R2*
13	(Ma et al., 2021)	Onion competency model	Identification of military nurses' competencies, insights for nurses' training	Qualitative content analysis, adoption from Spencer and Spencer (1993)	Motive, trait, identity, knowledge, skills, and abilities	*R11*
14	(Nguyen, 2022)	Conceptual framework of competency	Catalogue of Industry 4.0 competencies for low middle-income countries	Conceptual framework adopted from literature, catalogue—survey and Delphi study	Set of competencies (knowledge, skill, ability, personality); competence domains (cognitive, interpersonal, intrapersonal, technical)	*R1*
15	(Paquette et al., 2021)	COMP2 competency ontology	Competency-based personalisation in learning environments	Ontology development process	Generic skills, knowledge, (optional) performance indicators; competency descriptors: actual, prerequisite and target; competency comparison	*R4*
16	(Salman et al., 2020)	Synoptic view of competence	Developing a holistic framework, defining the concept of competence	Literature review of competence concepts in 1959–2020 period	Visible/hard aspect (knowledge, skills, behaviour); hidden/soft aspect (traits, motives, attitudes, values, and self-image)	*R1*

Table 2 (continued)

ID	Authors	Model's Label	Purpose of the Model	Development Method	Operationalisation	R.A.*
17	(Schulze et al., 2017)	Model of communication competence	Convergence of KSAOs for face-to-face/text-based computer-mediated communication	Spitzberg's model of communication competence adopted by Keyton (2015)	KSAOs, and outcomes of competence interaction	*R1; R13*
18	(Shum et al., 2018)	Model of hospitality leadership competency	Practical and educational implications in hospitality management	Adoption of Competency Dictionary (Harvard University, 2014)	Cluster of related skills (abilities to exhibit behaviours) and behaviours (observable and measurable actions to exhibit in job)	*R15*
19	(Song et al., 2022)	Competency index system framework	Theoretical and practical significance for selecting and developing talents	Literature review, expert interviews, combined with the model of McClelland (1973)	Competency index dimensions: nursing knowledge, professional ability, professional attitude, personal quality	*R7*
20	(Suhairom et al., 2019)	Star-Chef Competency Model	Culinary professional profile conceptualisation, insights on competencies	Thematic analysis of literature sources and interviews	Technical and non-technical competencies, personal quality, physical state, self-concept, motives	*R15*
21	(Uhm et al., 2017)	BIM competency elements	BIM professional profile conceptualisation, insights on required competencies	Frequency analysis, application of the O*NET Content Model	Common, essential, job-specific competencies consisting of skills, knowledge, educational background, experience, and licenses	*R3; R5*
22	(von Treuer & Reynolds, 2017)	Psychology competency model	Identification of key competencies required to practice psychology	Delphi study and focus groups	Core (knowledge, skills, behaviours, activities) and meta competencies' dimensions	*R15*

Table 2 (continued)

ID	Authors	Model's Label	Purpose of the Model	Development Method	Operationalisation	R.A.*
23	(Wilhelm et al., 2019)	Le Boterf definition of competences	Integration of competence orientation in education	Model of Le Boterf (2008) adopted by Stiftung Umweltbildung Schweiz (2014)	Inner (experiences, knowledge, skills, abilities) and external resources expressed through competences, and resulting in performances	*R6; R14*
24	(Zandbergs et al., 2019)	Universal competence model	Competence management services at non-formal education institutions	Modification/reuse of existing competence frameworks	Knowledge, skill, attitude; competence level to grade the performance	*R2*

* Research Area (R.A.): *R1*—Business & Economics, *R2*—Computer Science, *R3*—Construction & Building Technology, *R4*—Education & Educational Research, *R5*—Engineering, *R6*—Environmental Sciences & Ecology, *R7*—Health Care Sciences & Services, *R8*—Information Science & Library Science, *R9*—Mathematics, *R10*—Mathematical Methods in Social Sciences, *R11*—Nursing, *R12*—Operations Research & Management Science, *R13*—Psychology, *R14*—Science & Technology—Other Topics, *R15*—Social Sciences—Other Topics, *R16*—Telecommunications

models, these concepts do correspond to the definitions of "models of competence structures" and "models of competence levels" given by Hartig and Klieme (2006) and Klieme et al. (2008). These two groups of theoretical models indeed perfectly complement each other, since when a "model of competence structures" is integrated in a certain competence framework or another properly described context, the "model of competence levels" becomes operative to measure or evaluate an outcome of competences' interaction.

The next chapter will synthesise these two concepts in the form of competence model and framework definitions, based on which a taxonomy of competence models is developed.

3 Taxonomy of competence models

3.1 Taxonomy development

As highlighted before, it is recommended to apply an iterative approach to taxonomy development for deriving a useful classification. Since no similar classification was revealed among the surveyed papers which could serve as a starting point (for a first iteration of taxonomy), development ab initio is required.

A central problem in taxonomy development is a selection of the relevant characteristics that are "mutually exclusive and collectively exhaustive" (Nickerson et al., 2013). At the beginning of development process, a meta-characteristic serving the purpose of the taxonomy should be selected, after, characteristics are to be determined, which are then grouped into dimensions. In case of the current taxonomy, the main meta-characteristic is a competence model; the characteristics include, by now, development method, purpose, and constructs' operationalisation, which need to be synthesized further. The challenge here is not only to derive additional characteristics, using both inductive and deductive approaches, but to group them in relevant and meaningful dimensions. Bailey (1994) has specifically highlighted that finding the "appropriate conceptual labels" could be difficult and particularly challenging is to "incorporate them into existing bodies of theory". Additionally considering the previously mentioned ambiguity of competence-related concepts, an understanding of paradigms like *construct*, *model*, and *framework* is needed to develop a respective categorisation.

According to Stenner and Rohlf (2023), *constructs* are "the means by which science orders observations", which are created through inductive methods, including creation of construct labels to express respective hypotheses. Transition from theory to model happens when constructs, – as a complex idea or as a concept derived from simpler ones – are validated or embedded "within a larger theoretical framework" (L'Abate, 2013). As defined by McGinnis and Ostrom (2014), *frameworks* "organize diagnostic, descriptive, and prescriptive inquiry" and "attempt to identify the universal elements" relevant for the theories in the same domain; while a *model* comprises a "manifestation of a general theoretical explanation in terms of the functional relationships among independent and dependent

variables important in a particular setting". To sum up, a *competence construct* may be considered as a complex concept made-up by various sub-constructs.

Based on these considerations, the next two working definitions of a competence framework and model are derived:

> *Competence frameworks* represent a set of terms describing which competences and/or competence (sub-) constructs are foreseen for a specific purpose. When a *competence construct* enables observing various functional relationships among its sub-constructs, it becomes then a *competence model*, which is preferably but not necessarily embedded in a competence framework

To uncover possible functional relationships and conceptual labels, a definition of models given by Knuuttila (2011) is adopted; models are defined by the scholar as "epistemic tools, concrete artefacts, which are built by various *representational means*, and are constrained by their *design* in such a way that they enable the study of certain scientific questions and learning through constructing and *manipulating* them". Additionally, Hughes (1997) addressed the representational capacity of models through *denotation, demonstration*, and *interpretation*, namely what meaning elements of a model have, what internal dynamic leading to new conclusions a model has, and what can it demonstrate back to the world.

The highlighted terms and other characteristics of models given by the scholars, including the definitions of models of competence structures and levels (Hartig & Klieme, 2006; Klieme et al., 2008), provide a source for the conceptual labels which we developed for the taxonomy representation (Fig. 6):

- *Denotation of Underlying Dimensions* define the ways in which constructs of competences can be expressed,
- *Flexibility of Constructs* describe how competence (sub-) constructs can be operated and manipulated,
- *Representational Means* summarise forms and media with which competence constructs can be represented and clustered if applicable,
- *Demonstration of Continuous Progression* reflects the internal dynamic of competence (how it develops over time, measured on a scale),
- *Interpretation of Continuous Progression* tells how the demonstration of competence constructs can be interpreted, and
- *Intended Purpose* justifies how and for what the competence model was designed, outlining possible applications realised in competence (management) systems.

As may be concluded from the context above, the first three labels reflect competences as models of structures, the next two labels categorise models of levels, and the last one shows the outcomes of combining these two groups of models in a system. Technically, these conceptual labels serve the aim to systemize dimensions, used to group various characteristics of competence models.

	Conceptual label	Dimension	Characteristics' categorisation				
Competence structures	Denotation of Underlying Dimensions	sub-constructs	none	input-based[14,18,23]	output-based[9,14,17,18,23]		
		type	actual[1,5,11,15,24]	prerequisite[1,15]	target[1,5,11,15,24]		
		evidence grade	none	hidden[16,20]	visible[8,15,16,20]		
	Flexibility of Constructs	conceptualisation	atomistic[1,2]	holistic[2,6,11,16,22,23]			
		contextualisation	specific[2,5,8,15,17,23]	general[2,5,15]			
		scaling	binary[2,11]	continuum[2,11]			
		dynamic change	acquisition[11,15,23]	loss[1,11]	fatigue[11]		
		interrelation	none	comparison[9,10,15]	interaction[11,17]		
	Representational Means	clusters	none	hierarchy[1,4,11]	dimension[6,16,22]	set[3,10,14,18]	type[12,15]
		modes	graph[1,11]	mathematical notation[1,10,11]	natural language[5,15]		
		media	abstract[10,15]	catalogue[14]	codebook[6,12]	ontology[15,24]	tool[1,11]
Competence levels	Demonstration of Continuous Progression	competency	emerging[2]	developing[2]	secure[2]		
		experience	quantification of related work experience/licenses[11,21,23]				
		proficiency	(1…5) scale[3,7]				
		mastery/expertise	(1...10) scale[4]				
	Interpretation of Continuous Assessment	performance	beginner[5,15]	intermediate[5,15]	advanced[5,15]	expert[15]	
Synthesis of both	Intended Purpose	standardisation	profile description[3,6,13,20-22]	integration of frameworks[2,7,12]			
		assessment	individual assessment[1,24]	cognitive diagnosis[10]	work performance[11]		
		resources allocation	optimal assignment[1,4,9,11]				
		training processes	learning personalisation[5,8,15]	design of training/evaluation[2,13,18,19]	gap evaluation[8,9]		

Fig. 6 Taxonomy of competence models

3.2 Taxonomy description

Below, the conceptual labels grouping the taxonomy dimensions are described in more detail, including a further explanation of taxa. Each category of characteristics represent a so-called taxon (Nickerson et al., 2013), ID's mentioned as a superscript in relevant taxa refer to the sources (Table 2), where this particular characteristic is used.

Denotation of underlying dimensions As mentioned above, this label underlines ways in which constructs of competences can be expressed.

- Possible *sub-constructs* of a competence can be described by its input-based (competency, knowledge, skill, ability, attitude, trait, motive, value, self-image, experience) and output-based (action, activity, behaviour, performance, context) characteristics, or a competence itself may become an input for a to-be-acquired, output competence. This phenomenon is highlighted by Le Deist and Winterton (2005) in their holistic model of competence: a meta-competence is considered as an "input that facilitates the acquisition of output competences" at the base of cognitive, functional and social competences. Although, deconstruction is not always a case: Bohlouli et al.

(2017) use a competence tree, where a competence is constituted by its textually described sub-competences. This doesn't prevent a competence model to be flexibly used for the competence assessment; or as shown by Fernández-Sanz et al. (2017), in some frameworks, competences are listed in parallel to knowledge and skills' elements, and not on the level above, where these elements would be part of a competence concept. As mentioned above, among usual sub-constructs such concepts like competency, knowledge, skill, ability, attitude, behaviour, trait, motive, value, self-image, experience, and context are listed, which are sometimes grouped in a KSA or KSAO term, where "A" interchangeably stands for ability or attitude. The correct usage here is "ability" as a part of KSA taxonomy introduced by Stahl and Luczak (2000). According to this taxonomy, knowledge and skills relate to a specific task and may be trained and educated; while abilities relate to individual traits, which are not influenced a lot by education and training. Gasmi and Bouras (2017) describe a competency as KSA, too, and consider the same nature of competency being an outcome of a training or a requirement for a certain occupation. Wilhelm et al. (2019) highlight the same attribute of inner resources, to which KSA together with experience are affiliated, since only inner resources can be trained, which are expressed through competences into performance. Nguyen (2022) use the same input-/output-based approach to conceptually describe individually- (knowledge, skill, ability, and personality) and socially situated activities and behaviours. Schulze et al. (2017) employ KSAOs to predict communication outcomes, and Shum et al. (2018) specify that skill, as a part of competency, reflects an ability "to exhibit behaviours", which are in its turn "observable and measurable actions". Therefore, sub-constructs can be grouped as input- or output-based, or none of it.

- To underline a span, typical for competence, three *types* are employed, namely, actual, prerequisite, and target. After acquisition, a competence is treated as acquired, which can be matched with a required one; these terms are also mentioned as actual or available, and requested competences. To put these characteristics on the homogenously continuous scale, the terms provided by Paquette et al. (2021) are adopted, since the authors see the process of competency acquisition as "a long-term process that can occur in a variety of acquisition contexts"; accordingly, a prerequisite competency means a minimum level required to engage in a certain activity, and a target one – a maximum level of competency.
- A competence may have sub-constructs which can be described by a certain *evidence* grade. When no evidence of a competence can be confirmed, it means that this is either not existing or it is difficult to evaluate as the subconstructs were hidden. Competence models adapted from the Iceberg model of competence Spencer and Spencer (1993) operate with such hidden and visible characteristics of competences. In their "synoptic view of competence", Salman et al. (2020) distinguish between visible/hard and hidden/soft aspects, where the latter one underline attributes "that tend to be deeper and pivotal to personality" in comparison to visible, apparent individual characteristics; the authors underline that together, these characteristics determine how a person performs in a job,

an output of which can be visible or not. Suhairom et al. (2019) simplify the "visible competency" by assigning to it only qualification and experience, but it also arises from the "hidden" one and represents underlying capabilities and motivations. Gaeta et al. (2017) see the same evolving pattern, but their definition of evidence is the same as later discussed by Paquette et al. (2021): they operate with the evidence concept to confirm (with a certain confidence level) an acquired competence, which may be supported with specific documents and performed activities. Based on this discussion, we grade evidence as visible, hidden or none of it.

Flexibility of constructs Six categories, namely atomistic/holistic (conceptualisation dimension), binary/continuum (scaling dimension) and specific/general (contextualisation dimension) are taken from Child and Shaw (2020); although authors applied these distinctions to characterize competency frameworks' purposes, as will be shown, those can be also applied to characterize competence models, too.

- Holistic vs. atomistic characteristics of *conceptualisation* given by Child and Shaw (2020) underline a relation of competency statements towards overall abilities of an individual. Salman et al. (2020) study the concept of competence holistically, and provide a synoptic view of competence, which reflects an interaction of its elements. Same as Korytkowski (2017), who considers relations between competences. An example of an atomistic competence conceptualisation may be found in the work by Bohlouli et al. (2017), where one of the competence assessment approaches was based on multiple choice questions, a so-called "checklist style" highlighted by Child and Shaw (2020). In general, the holistic characteristic of a competence model enables a broader study of its concept by uncovering the interrelation of its sub-constructs, while the atomistic one may generate more precise assessment scenarios. A disadvantage of an atomistic view is that it can limit the conceptual view on a competence considering only one specific knowledge domain.
- Child and Shaw (2020) consider how general and specific *contexts* are integrated into competency frameworks, and in frames of competence models, El Asame and Wakrim (2018) define these characteristics as being "competent in a context but may not be so in a different context", while Paquette et al. (2021) treat these as "a more generic or more specific resource according to the knowledge components". Schulze et al. (2017) study the Spitzberg's model of communication applied in two specific modes of communication, while Gaeta et al. (2017) and Paquette et al. (2021), in addition to the context of competence performance, consider where it has been acquired.
- *Scaling* dimension is presented by binary and continuum characteristics, which are taken from Child and Shaw (2020) the way they are: how a competence can be measured is relevant for both competence frameworks and models. The binary characteristic underlines whether a person is competent, while the continuum one describes various levels of competence. As already highlighted above, the competence is often conceptualized as expression of resources into performance, which can be then measured; but since the selected papers describe various

methods of qualitative and quantitative measurement of competence sub-constructs, which cannot be homogenously categorised, the continuum characteristic of competence models is extended to a separate conceptual label *Demonstration of Continuous Development* in the section on competence levels in Fig. 6.

- Korytkowski (2017) highlights that a competence described as a continuous parameter may be considered as a *dynamic* one, too, that changes over time "due to training, learning, forgetting and fatigue". The last term expresses an exhaustion of competence, while the first two aspects may be grouped as a competence acquisition, since, as highlighted by Wilhelm et al. (2019), a competence "can neither be transferred nor taught, but only acquired in a specific context". Nevertheless, Korytkowski (2017) use learning and forgetting terms to describe acquisition and loss of competences, respectively. In addition, Bohlouli et al. (2017) use the notion of a loss or gap function to capture the deviance between acquired and required competence data scores. Based on these considerations, we introduce the dimension *dynamic change* with the categories acquisition, loss, and fatigue.
- The fact that competences are *interrelated* is highlighted by Korytkowski (2017). Indeed, sub-constructs in simple competence models may be considered as stand-alone concepts, while in complex ones, sub-constructs allow comparison and interaction with each other. While Heller et al. (2017) considers a pairwise incomparability of competences, Gasmi and Bouras (2017) study matching of two competence profiles enabled by comparison of quantified competence levels, and Paquette et al. (2021) provide several scenarios on competence comparison: using actual and prerequisite/target competences to measure a respective gap; applying a meta-feature of "association between competencies" in various ontology models; and employing skill and performance scales "to compare manually any two competencies". A synergy of competences and interaction expressed through relation forces between competences is considered by Korytkowski (2017), the latter one can be assessed by applying a "description of the required competences on the basis of the percentage or temporary share". On the level of sub-constructs, Schulze et al. (2017) study outcomes of KSAOs' interaction to find differences between performances in two modes of communication. This leads to the *interrelation* categories of comparison, interaction, and none of them.

Representational means This label describes how competences are noted or coded. It contains three dimensions, namely *clusters* of competence constructs, expressed in different *modes*, and *media*, in which a manipulation is "materialised" (Knuuttila, 2011).

- The competence elements may be *clustered* in a hierarchy (Bohlouli et al., 2017; D'Aniello et al., 2021; Korytkowski, 2017), in a dimension (Feng & Richards, 2018; Salman et al., 2020; von Treuer & Reynolds, 2017), in a set (Costa & Santos, 2017; Heller et al., 2017; Nguyen, 2022; Shum et al., 2018), or grouped by its type (Li et al., 2020; Paquette et al., 2021). One may argue in regard to the terms applied: e.g., Feng and Richards (2018) distinguish among four types

of professional competency based on the typology of Le Deist and Winterton (2005), but as highlighted above, the holistic model is rather based on dimensions than just competence types. Similarly, von Treuer and Reynolds (2017) use terms of meta competencies' dimensions to highlight their functionality across core competencies' dimensions. Li et al. (2020) operate with terms of sets and dimensions as well, but the description of competences is based on attributes and performances, making it rather a type or category of descriptors.

- To enhance a representational capacity, such *modes* like graphs, mathematical notations, and means of natural language may be employed. Bohlouli et al. (2017) and Korytkowski (2017) employ graphs to express competence models but considering that diagrams, charts, knowledge graphs, and other pictorial representations may be summarised under the graph term, more competence models using graphical expression can be classified as graphs, too. Heller et al. (2017) and Korytkowski (2017) employ mathematical notations mainly while describing the models; whereas it is often a case, when at least competence assessment is performed using formulas as done by Bohlouli et al. (2017). Natural language can be perceived as the most used mode but in this taxonomy, natural language strings are meant, applied to formally captured competences in such specifications like RDCEO, HR-XML and ASN-DL (El Asame & Wakrim, 2018; Paquette et al., 2021).
- The categories of *media* may be used to "produce" representations of competence models: abstract media, catalogues, codebooks, services, and tools. Heller et al. (2017) operate with "abstract skills", and in general employ mathematical notations, where a certain level of abstraction is required. Paquette et al. (2021) highlight that abstraction is required, too, for transforming competency proposals into software ontology format; an ontology itself operates with abstracted entities, representing "people, real-world objects and also abstract concepts". Nguyen (2022) employ a competence model to catalogue Industry 4.0 competencies, namely a "standardized list of competencies" based on the O*NET Content Model (U.S. Department of Labor/Employment and Training Administration, 2023). To analyse representation of a digital curator's profile in related literature sources, Feng and Richards (2018) develop a coding scheme, which is not only extending the holistic competence model of Le Deist and Winterton (2005) but may represent a competence model by itself, realised in the form of a codebook. Li et al. (2020) create a codebook of competency variables, later grouped in 26 categories of international project manager competences. Paquette et al. (2021) highlight that a developed ontology may be employed in a variety of software-enabled services, and Zandbergs et al., (2019) describe an ontology to build a competence management service for non-formal education, aiming at abstracting from individual competence interpretation, which differs "from one framework to another". Bohlouli et al. (2017) describe a framework of a tool, which addresses vocational training purposes too, together with job assignment and recruitment processes. Similar, Korytkowski (2017) addresses performance of employees by providing a concept of a tool, describing capabilities of workers who perform repetitive tasks. Thus, we assume that the *media* categories list but are not limited to abstract, catalogue, codebook, tool, and ontology.

Demonstration of continuous progression The *scaling* dimension under *Flexibility of Constructs* label, assumed either binary or continuum scaling of a competence, the continuum characteristic though is rather big and needs to be differentiated separately.

- Child and Shaw (2020) describe progression indicators of a *competency*, using the "emerging, developing, and secure" levels. These levels capture a certain stage of learning, which needs to be developed before starting with the next one: emerging means that "learners have been taught the skill but only occasionally apply their understanding", developing level occurs when "learners begin to apply their understanding", and secure – when they "consistently work at this level". Another scale in educational context suggested by Paquette et al. (2021) considers competency from "lower" to "upper" levels. And in frames of education/industry collaboration, Gasmi and Bouras (2017) employ three competency levels: knowing, capable, competent, which specify "the required level of a competency in an occupation"; in addition, the authors suggest assigning numerical values to these levels to enable relevant computations. Nevertheless, such a layered, built one on another, consideration of progression indicators suggested by Child and Shaw (2020) is perceived by us as more sophisticated, and therefore emerging, developing, and secure characteristics of a competency sub-construct are adopted.
- *Experience* is often mentioned to measure how an individuum is competent based on previously performed, relevant work. Korytkowski (2017) describe experience by the number of finished repetitive tasks performed by a worker. Other sources suggest a quantification of relevant work experience, represented by a duration of time, trainings, or acquired licenses (Uhm et al., 2017; Wilhelm et al., 2019). For instance, Uhm et al. (2017) derive the "related work experience" element from the O*NET Content Model (U.S. Department of Labor/Employment and Training Administration, 2023) to analyse how many years of experience an employee should have, depending on a certain BIM role. Additionally, the authors provide BIM job description terms to describe which BIM experience is needed for every level of the O*NET elements.
- Levels of *proficiency* and *mastery* or *expertise* were found in the considered papers to be put on a scale from 1 to 5, and 1 to 10, respectively. Costa and Santos (2017) and Fernández-Sanz et al. (2017) employ the e-Competence framework (European Commission, 2014) to operate with ICT competency profiles, which are ranging from 1 to 5 in their proficiency levels. In their "lightweight competence semantic model", D'Aniello et al. (2021) represent competencies as knowledge, skills, and attitudes, represented by "mastery and expertise" parameters, put on a "given scale", which, for instance, could range from 0 to 10, namely, from "no competence" to "very expert in that competence". As can be seen, this ranging in both cases is very subjective, and is not a standardised way to measure relevant parameters. For our taxonomy, we assume that levels of *proficiency* and *mastery* or *expertise* can be represented by numeric scales.

Interpretation of continuous progression After a certain level of competence progression is demonstrated, conclusions from a demonstrated level may be drawn on how an individual is competent and how the competence is progressing.

- As highlighted by authors of several selected papers of this study, only outcomes of competence application like activities, behaviours and other actions of *performance* can be measured. El Asame and Wakrim (2018), in their model of learning, use four levels of performance: beginner, intermediate, advanced, and mastery, while Paquette et al. (2021) suggest using "expert" level instead of "mastery". At the same time, the latter authors consider performance indicators from a broader perspective, namely "frequency, scope, autonomy, complexity and context", which can be combined to either classify a competency into one of performance classes (awareness, familiarisation, productivity, and expertise) or to assess a competency on (1…10)-performance scale. The mentioned classes can be also ranged between "beginner" and "expert" performance levels, and therefore this scale is respectively adopted to interpret an individual performance.

Intended purpose This label categorizes "the established empirical findings" as outcomes of the competence models' application, realised by the competence (management) system. This label justifies a synthesis of competence structures and competence levels.

- As it was previously defined (s. working definitions given in sub-chapter 3.1), a competence construct, if it enables the description of various functional relationships among its sub-constructs, becomes a competence model, which is preferably but not necessarily embedded into a competence framework. This way, authors of several selected papers employed a competence model to *standardise* or conceptually describe a competence framework relevant for a certain occupational role. In addition, Costa and Santos (2017), Suhairom et al. (2019) and Uhm et al. (2017) mention quantification possibilities of relevant competence elements, while Feng and Richards (2018), Ma et al. (2021) and von Treuer and Reynolds (2017) describe dimensions and categories or types of competencies required to practice certain occupations. The integration of competence frameworks into one represents another type of standardisation. Fernández-Sanz et al. (2017) analyse several frameworks where the ICT occupation is represented, and through entity relationships a "consistent model" of an e-skills matching tool is developed. Li et al. (2020) study project management standards and project manager profiles to conceptualise a profile of a "competent international project manager". Child and Shaw (2020) develop a "purpose-led approach" of competency frameworks' development, which is later used to categorise eight competency frameworks.
- *Assessment* of competences is another usual application of competence models. Bohlouli et al. (2017) and Zandbergs et al. (2019) address individual competence

assessment to evaluate a competence gap an employee may have; in both studies, the gap is considered as a difference between acquired and required competence levels. A term of cognitive diagnostic comes from the psychological domain, the main purpose is the diagnosis of skills, based on "a probabilistic modeling of data" (Heller et al., 2015). Evaluation of worker performance is considered by Korytkowski (2017), aiming at a better description of capabilities possessed by multi-skilled workers. Therefore, we categorize the competence assessment methods into individual assessment, cognitive diagnosis, and work performance. This is probably not an exhaustive set of categories but for the time being it is the set which can be derived from the analysed literature.

- A problem of *resources allocation* (e.g., mapping people to tasks) was addressed in the selected papers on a one-to-one basis, for instance, when matching a required competence with an actual/acquired one, or on a many-to-one basis, when forming a team to work together on a given project. Bohlouli et al. (2017) claim that their competence analytics model can be applied in various scenarios, and optimal job assignment is one of them. Gasmi and Bouras (2017) propose an ontology to model a matching process between individual curriculum and occupation competence profiles. D'Aniello et al. (2021) address a problem of team formation, where a team would consist of members who possess adequate competencies required for a given project.
- Competence models are widely applied to manage *training* processes and other educational *processes*. El Asame and Wakrim (2018) develop a model for training and education to enable learners maintaining their learning experience based on extensive competence description. Similarly, Gaeta et al. (2017) suggest an approach helping employees engage in learning activities based on the identified gaps. Paquette et al. (2021) develop a competency ontology to enable a personalisation of learning environments. Design of trainings and educational initiatives in the field of nursing and healthcare services are addressed by Ma et al. (2021) and Song et al. (2022), and a similar problem in hospitality management field is addressed by Shum et al. (2018); while Child and Shaw (2020) suggest a design method for competence framework development, which can be applied in any field, including planning of educational journeys and their evaluation. Gasmi and Bouras (2017) study an evaluation of a competence gap which should be precisely addressed by an individual, while Gaeta et al. (2017) address a bigger issue, namely "gap between higher education outcomes and the industry needs". Therefore, we assume that with the help of competence models management of training processes can be categorized into learning personalisation, training and evaluation processes design, and gap evaluation procedures.

4 Discussion

This research contributes to overcoming the conceptual ambiguity of competence-related concepts by unpacking the resources and power of formal competence models, which capture formal notations of competence profiles. Nevertheless, it is difficult to deal with the quantity and complexity of the presented concepts and

definitions. Figure 7 aims at further explanation and describes a flow of the concepts and the derived findings in the form of a concept map.

The definitions of *models of competence structures* and *levels* given by Hartig and Klieme (2006) and Klieme et al. (2008) helped not only to form the search and selection strategies but also were actively used in the developed taxonomy. Nonetheless, in the selected papers the difference between models and frameworks was not clearly addressed, moreover, the terms were even sometimes used together. Therefore, the working definitions of a competence construct, model and framework finally state the differences between the concepts and invite scholars to distinguish carefully between those.

This paper puts the focus on competence models, not on competence frameworks. In addition, the focus was laid on understanding the competence concept than just consolidating various definitions of it. Nevertheless, such consolidation helped Salman et al. (2020) to develop a definitional framework of competence, consisting of visible/hard and hidden/soft aspects, which were adopted in the current taxonomy. Important to mention, that their framework is strongly based on the Iceberg model of Spencer and Spencer (1993), since the respective research focused on a typology of competences rather than possible operationalisations, and extensively addressed a historical development of theoretical research on competences. Similarly, study of competence definitions enabled El Asame and Wakrim (2018) to develop a competence model for training and education.

Such competence models integrate both the models of structures and the models of levels, if needed. When these definitions are in place, "users" of competence-based research findings will be able to eliminate the ambiguity around competence-related concepts. Taxonomy development is one example how the definition was applied to derive respective conceptual labels, and dimensions constituted by models' characteristics (Fig. 6). In its turn, these are characteristics of competence models, with which one can operate to fulfil various purposes of the considered models (Table 2).

After comparing the overview and the taxonomy, one will notice that these concepts are related but the terms are not the same: this is done with the purpose of generalisation and providing once again a common vocabulary of formally captured competence models. For instance, Child and Shaw (2020) developed a binary distinguishment towards competence frameworks but since those binary

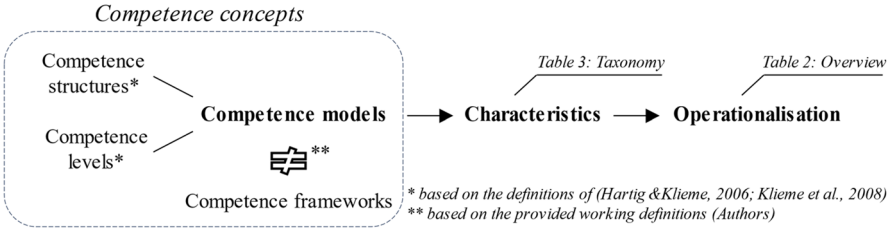

Fig. 7 Concept map of literature review's findings

characteristics were clearly defined, they were easily integrated in the taxonomy of competence models, too.

Following the descriptions of the developed taxonomy, a certain logic can be noted: first, a competence is deconstructed (if applicable), and described by its type and evidence grade. Such deconstruction is needed to (flexibly) operate with competence sub-constructs, which are then grouped in various clusters, and represented in various modes and media. In case the model was "flexible enough" and a continuum scaling of a competence was in place, this continuum can be put on levels to either demonstrate the competence progression or interpret respective competence assessments. Consequently, when competence structures "meet" competence levels, a certain system of competence profiles is enabled, which allows various scenarios like standardisation, human resource assessment, resources allocation, and training optimisation.

The taxonomy is "opened" on purpose with a characteristic of *none* sub-constructs since a competence is not broken down into sub-constructs in some cases. The next dimension, type of denotation, can be rather perceived as a level than a type, based on the used wording. But when it comes to switching occupations or job roles, the *target* state of a competence would reflect a new competence or a competence profile. *Evidence grade* of a competence contains an interesting characteristic called *hidden,* which also assumes soft aspects of a competence (Salman et al., 2020). Operationalisation of such soft aspects of a competence were not explicitly highlighted in the taxonomy as the selected papers describe more clearly how the *visible* or hard aspects are captured.

The *Flexibility of Constructs*-label represents various dimensions, and the most interesting dimension here is *interrelation*: it was not addressed in detail in the considered models, and as mentioned above, it would be particularly interesting to involve such *interaction* characteristics when it comes to assignment problems as examined by D'Aniello et al. (2021). The further investigation of the interrelation of competence sub-constructs may be a very relevant research topic, especially with respect to hidden or soft factors.

It is logically clear that if no deconstruction was performed, no clustering would take place neither, although clustering helps to structure competence sub-constructs for further manipulations. The dimensional characteristics though can be of the biggest interest thanks to the typology of Le Deist and Winterton (2005). A mode of mathematical notation is highly interesting, too, particularly when it comes to algebraic operations. At the same time this mode can limit either the competence description or application of competence models: in the first case, by simply assigning numeric values to competence sub-constructs the whole model can become too simplistic to produce expected outcomes, and in the second, users of competence management systems may need more introduction and explanation on how (mathematically described) models work. But such media as *tool* is supposed to eliminate possible complexities in applying *abstract* competence models in practice which may require "enormous efforts and dedicated personnel" (D'Aniello et al., 2021). It is also worth mentioning that following the methodology of Nickerson et al. (2013), characteristics should be "mutually exclusive and collectively exhaustive", which is obviously not the case

of *media* dimension: e.g., competence descriptions can be stored in catalogues and codebooks, which are integrated in tools as (abstract) databases.

The *competence levels* part of the taxonomy tells how competence models contribute to describing levels of a competence demonstrated, and how this demonstration can be interpreted. Demonstration starts from the learning path described by *progression* indicators, which are built on one another (Child & Shaw, 2020): to be *secure*, learners should first achieve *emerging* and then *developing* levels. These characteristics may relate to the experience dimension, too, but in the selected papers the "layered", multilevel view on experience was not covered. On the opposite, one can notice that the next three dimensions of *experience*, *proficiency* and *mastery/expertise* are rather an example for possible categories than a final and comprehensive set. For instance, *experience* dimension could have a binary distinguishment, too: experienced or non-experienced. But quantification of the relevant experience contributes to a wider range of possible operations with competence models. For instance, number of executed tasks' repetitions allows an estimation of how long it would take a worker to execute the same type of tasks (Korytkowski, 2017). But how much one should be experienced in months, years, or acquired licences is determined by the "owners" of a certain competence management process, same as with *proficiency* and *expertise* dimensions described by previously defined scales.

The conceptual label of *Intended Purpose* shows how both the models of competence structures, and the levels interact with each other to produce certain outcomes of a competence (management) system. The dimensions here are described rather by examples than characteristics, which are certainly not "mutually exclusive and collectively exhaustive" (Nickerson et al., 2013). Nevertheless, these examples demonstrate how powerful the competence models could be in addressing diverse issues in training, assessment, and resources allocation. The examples are interrelated in the purposes they address; that is to say, when a profile of a certain occupational role is captured, it can be used not only for standardisation but also for further assessment and training. For instance, one can check which competence sub-constructs are expected to be in place for the next level, and by training of which resources (s. *sub-constructs* dimension) this next level can be reached.

Reflecting on the derived taxonomy of competence models, we perceive the conceptual labels, dimensions, and respective characteristics as well-developed based on the integrative literature review. Nonetheless, the characteristics might be incomplete and sometimes serving as example on how to characterize a certain aspect of a competence model. Being a work-in-progress, this taxonomy synthesises the findings derived from the selected papers, during development of which several ambiguous competence concepts could be clarified. Even though the taxonomy should be validated and elaborated, as described in the next concluding chapter, it can be already used as a competence vocabulary or a checklist on available competence characteristics, and/or a tool, supporting competence model development.

5 Conclusions

5.1 Summary

This study provides a synthesis of retrieved competence models in the form of taxonomy based on an integrative literature review. On the way to this taxonomy, two other outcomes have evolved: an overview of competence models, formally describing and capturing competence profiles, and a working definition of a competence construct, model, and framework. The overview is useful by its own since it summarises competence models addressing various purposes in different research areas and ways of competence sub-constructs operationalisation; in addition, this summary shows how differently the competence models are approached and respectively labelled by authors. To address this ambiguity, a working definition of competence models and frameworks, as well as the taxonomy itself, had been developed, mostly operating with definitions of "models of competence structures", "models of competence levels", and those taken from philosophy of science body of knowledge. The latter one had to be consulted to reduce the bias and subjectivity in selecting the conceptual labels, as part of the taxonomy development process.

The first research question was about models of formally captured competences – what they are, and which types of these models exist in a recent literature. The overview of competence models (Table 2) has summarised recently developed models, the working definition in sub-chapter 3.1 clarified the difference between competence models and frameworks from the philosophy-of-science point of view, and finally, the taxonomy categorised the models in several dimensions.

The second research question inquired on similar taxonomies or typologies of competence models, which are already available and validated; and if not – how such taxonomy may look like. A rapid review at the beginning of the study, the integrative literature review method together with the exhaustive search and systematic selection processes have confirmed that there were no similar taxonomies already available in the relevant body of knowledge. Therefore, a new taxonomy ab initio was developed based on the critical analysis and synthesis approaches, and considerations from philosophy of science while creating relevant conceptual labels.

The third and last research question was devoted to characteristics and features of the (retrieved) competence models in respect to application and operationalisation scenarios. This question was covered by the taxonomy itself, which is discussed in detail in sub-chapter 3.2, where the conceptual labels cover the operational aspects of the models. Especially, the *Intended Purpose* conceptual label, as already highlighted above, can be considered as an outcome of the competence system, which evolves by merging two types of competence models, namely structures and levels, to enable certain application scenarios. Unfortunately, such fast evolving applications are rather driven by acceleration of digital technologies than by sound, well-established and contemporary competence research. This demand was proven during the study and respectively

addressed by synthesizing operational characteristics of recently developed models of competence. All involved stakeholders are highly encouraged first to follow the patterns of deep, theoretical research on competences, and only then take an advantage of available technologies. Such a conscious approach towards digital processing of individual competence profiles will advance a proper development of educational eco-systems.

5.2 Limitations and future research

The selected framework for taxonomy development assumes an iterative approach, which was not fully addressed by this study. This step, as well as additional literature research on every dimension of the taxonomy, would improve the content validity of the taxonomy. It will make the taxonomy a more generalised and complete tool, characterising any competence model in given dimensions and taxa. Another approach could involve expert reviews as it was done by Tett et al. (2000) or application of case studies as performed by Fuchs et al. (2019). In case of the latter approach, a formally captured competence profile could be tested by the taxonomy-based description. This will make the taxonomy an empirically tested research outcome.

The next two limitations are related to the methodology applied: to make this study feasible, a timeframe of the literature search was limited to six years, but it could consider more years, and additional data-driven approaches to filter the initially retrieved paper items. In addition, the taxonomy development method supposes a selection of characteristics, which are "mutually exclusive and collectively exhaustive". For instance, the last dimension of training optimisation considers "learning personalisation" and "design of training/evaluation" characteristics, which do not obviously correspond this exclusive/exhaustive condition.

In addition to the generalisation and validation of the taxonomy, further research on competence models will focus on a comparative analysis of competence models to define requirements of a new or meta competence model. This step together with the development of "theoretically sound and empirically tested competence models" (Koeppen et al., 2008) are important and necessary endeavours to be taken to unpack a high potential of formalised competence profiles.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request. Data sharing is not applicable to this article as no new data were generated in this study. Furthermore, primary and secondary sources supporting the findings of this study were all publicly available at the time of submission.

Declarations

Conflict of interest None.

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